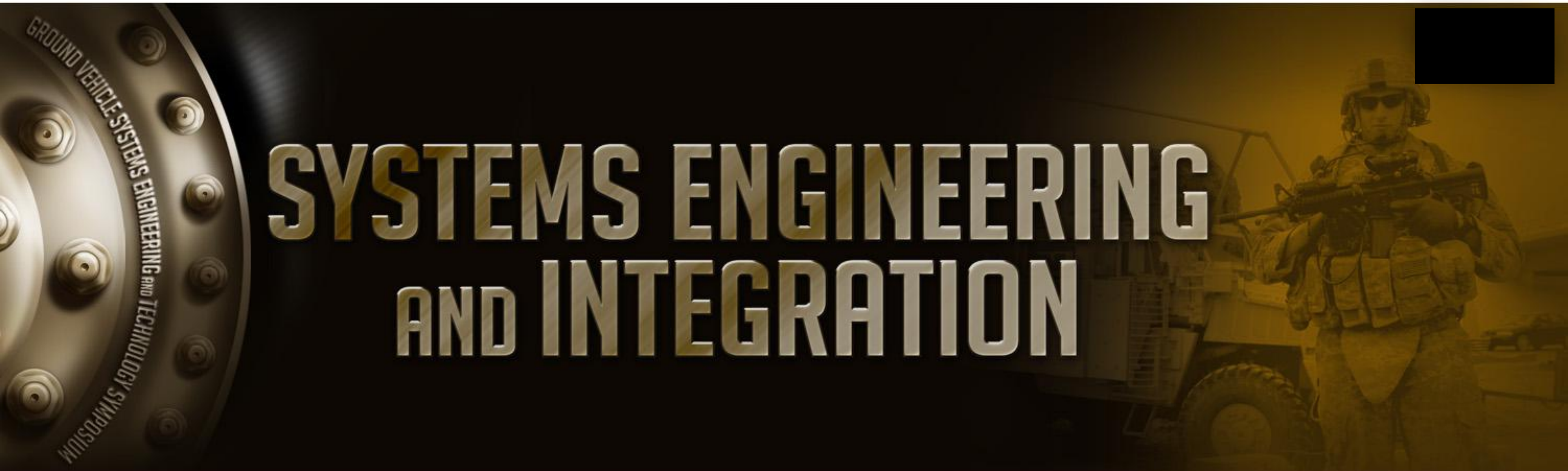

LESSONS LEARNED IN PERFORMING TECHNOLOGY READINESS ASSESSMENT (TRA) FOR THE MILESTONE (MS) B REVIEW OF AN ACQUISITION CATEGORY (ACAT)1D VEHICLE PROGRAM

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The 5 W's of MS-B TRA (what, who, why, when, where)

- What: A TRA is a systematic, metrics-based process that assesses the maturity of, and the risk associated with, critical technologies to be used in Major Defense Acquisition Programs.
- Who: It is conducted by the Program Manager (PM) with the assistance of an independent team of subject matter experts (SMEs).
- Why: Required by DOD! The TRA is used by the Assistant Secretary of Defense for Research and Engineering (ASD(R&E)) as part of the basis to advise the Milestone Decision Authority (MDA) whether the technologies of the program have acceptable levels of risk.
- When: MS-B Review is the decision gate between the Technology Development (TD) Phase and the Engineering & Manufacturing Development (EMD) Phase. One of the purposes of the TD Phase is to reduce technology risk and demonstrate critical technologies on prototypes in relevant environments.
- Where: During the MS-B Review, the program is required to show that the system/subsystem prototypes using the technologies have been demonstrated satisfactorily in a relevant environment (TRL6).

DoD TRA Guidance (4/2011)

- Latest TRA Guidance requires comprehensive technical risk assessment.
- The assessment should be based on objective evidence gathered during events, such as tests, demonstrations, pilots, or physics-based simulations. Based on the requirements, identified capabilities, system architecture, software architecture, concept of operations (CONOPS), and/or the concept of employment, the SME team will evaluate whether performance in relevant environments and technology maturity have been demonstrated by the objective evidence.
- If demonstration in a relevant environment has not been achieved, the SMEs will review the risk-mitigation steps intended by the PM and make a determination as to their sufficiency to reduce risk to an acceptable level.
- TRLs will be used as a knowledge-based standard or benchmark but should not substitute for professional judgment tailored to the specific circumstances of the program.

TRA PROCESS TIMING

TRA Processes

Complete TMA Outline
- Program planning (WBS, overall timing)
- Draft TMA Scope of Work
- Collect project information
- Review program data

Technology Assessment
- Assemble assessment
- Establish CTE selection criteria
- Establish CTE
- **Perform TRL assessment**
  - Agree on TRL criteria
  - Perform assessment on OEM technologies

Documentation
- Develop preliminary TMA report
- Summarize preliminary assessment
- Complete draft TMA report
- Complete final TMA report
- Incorporate updates

Reviews
- PdM
- Update
- PEO & Other Services
- ASA(ALT) Review + TMA Report
- OSD

TRA Time Estimate versus Actual

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Technology Maturity Assessment Tasks	Estimate (days)	Actual (days)
Project planning	15	15
Scope of work	3	3
Collect project data	20	50
Extract technology	15	25
Form SME Team	5	10
Link technology & KPP	2	3
Establish CTE criteria	5	3
Initial CTE screening	5	50
PM/ASA(ALT) Review		10
OSD CTE deliberation		20 parallel
CTE & TMA process brief		10
Collect TRL6 requirements		20
SME Tailor TRL checklist	8	10
Combine CTE TRL checklist & TRL6 technical requirements	4	5
SME TRL6 metrics review		5
PM TRL6 metrics review		10
Test data collection		95 parallel
Organize CTE data		15
Assess CTE technical risks	15	20
Collect SME risk assessments		4
PM review of assessments		5
Finalize CTE assessments		10
Fill in TRL checklist		95 parallel
Calculate TRL/MRL/PRL	20	5
Summarize all assessments	10	10
ASA(ALT) TRL & BOE review		10
Write draft TMA report	50	30
Internal reviews	5	5
Finalize TMA Report	10	10
Total	192d=38wk =9m	353d=71wk =16m

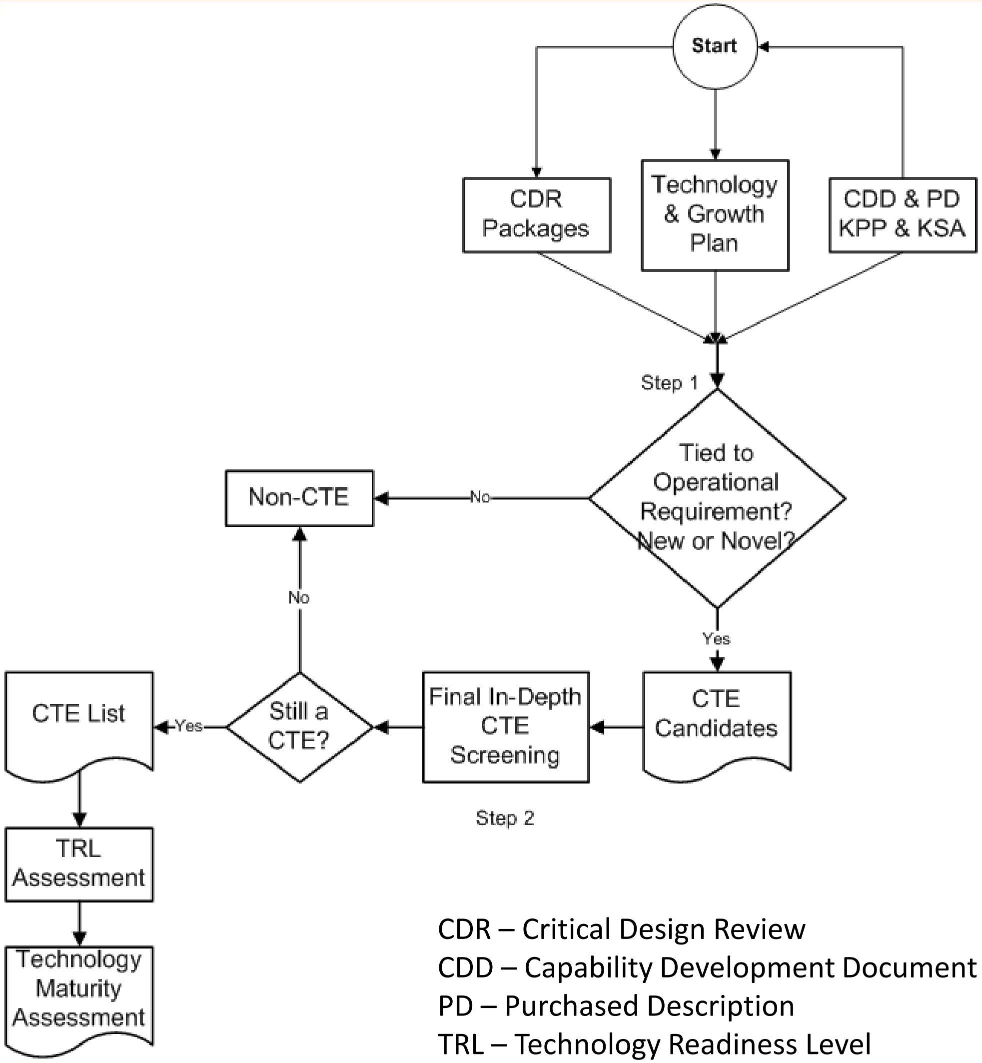
The original estimate was 9 months to complete the whole TRA process.
The actual time was 16 months.

Lesson: Many collaboration reviews and information organization tasks were not included in the original planning. If included, the project took 1.8 times longer. A better estimate on TRA project timing should include time required to conduct reviews and information gathering and organization.

Lesson: The time required to identify the technologies for each contractor can be significantly reduced if the information is provided by the program engineers or the contractors.

CRITICAL TECHNOLOGY ELEMENTS SELECTION PROCESS

JLTV TRA Process



Lesson: Before requesting support from subject matter experts (SMEs) and information from the PM, develop a flowchart to show the TRA process and a swimlane chart to show the detail TRA steps combined with roles of each participating organizations. These charts demonstrate how and when team members have to rely on each other to complete the TRA project..

CDR – Critical Design Review
CDD – Capability Development Document
PD – Purchased Description
TRL – Technology Readiness Level

Technology Requirements

Lesson: *To determine all key requirements associated with a technology, set up a functional requirement tree using the Capability Development Document (CDD) with identified KPPs and KSAs and/or Purchase Description (PD) requirements if available.*

- **Mobility**
  - KPP 1
  - NKPP 1
  - NKPP 2
  - NKPP 3
  - NKPP 4
  - NKPP 5
  - NKPP 6
  - NKPP 7
  - NKPP 8
  - NKPP 9
  - NKPP 10
- **Transportability**
  - KPP 2
  - KPP 3
  - KPP 3
  - NKPP 11
  - NKPP 12
  - NKPP 13
- **Net-Ready**
  - KPP 4
  - KPP 5
  - NKPP 14
  - NKPP 15
  - **C4ISR**
    - NKPP 16
    - NKPP 17
    - NKPP 18
    - NKPP 19
- **Survivability**
  - KPP 6
  - KPP 7
  - NKPP 20
  - NKPP 21
  - NKPP 22
  - NKPP 23
  - NKPP 24
  - NKPP 25
  - NKPP 26
- **Sustainability**
  - NKPP 27
  - NKPP 28
  - NKPP 29
  - NKPP 30
  - **Reliability**
    - KSA 1
    - KPP 8
    - NKPP 31
    - NKPP 32
    - NKPP 33
- **Human Factors**
  - NKPP 34
  - NKPP 35
  - NKPP 36
  - NKPP 37
- **Trailer**
  - NKPP 38
  - NKPP 39
  - NKPP 40
- **Ownership Cost**
  - KSA 2
  - NKPP 41
  - NKPP 42
  - NKPP 43

Lesson: Each system requirement should be accompanied by acceptance criteria and verification test procedure. Each test procedure should be based on some functional analysis and mission profile. If it is not, the program can be at risk of failing some relevant environment verification test in the future.

Note: Additional requirements can be added as required.

CTE Selection

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The MS-B Review mainly focused on the CTEs which are defined by 2 main criteria.

1. The system being acquired depends on this technology element to meet Key Performance Parameters (KPP) or Key System Attributes (KSA). (see the following requirement tree and vehicle work breakdown structure (WBS)).
2. The technology or its application is new or in an area that poses major technological risk during design/demonstration.

These criteria are expanded upon in the following table to assist the CTE identification process.

CTE Selection Criteria

	Critical Technology Element Screening Criteria	Y/N	Y/N
1) Critical	Directly impact an operational Requirement threshold (KPP or WBS)?		
	Significant impact on an improved delivery schedule?		
	Significant impact on program affordability?		
AND			
2) New or novel application	Is the technology new or novel?		
	Is the technology modified?		
	Tech repackaged such that a new relevant Environment is realized?		
	Expected to operate beyond design intention & demonstrated capability?		
Or			
3) High Risk	Is the technology in an area that poses major technological risk during detailed design or demonstration?		

Technological Risk During Detail Design & Demonstration

Lesson: In order to determine if there were any major technological risks associated with a technology during detail design and demonstration, many engineering supporting documents have to be reviewed:

1. *Engineering analysis*
2. *Test results*
3. *Failure analysis and corrective action reports (FACAR)*
4. *Documented design risk and issue matrixes*
5. *Requirement compliance matrix*
6. *Failure mode and effect analysis (FMEA)*
7. *Modeling and simulation analysis*
8. *Boundary diagrams and interface analysis*
9. *Trade studies*
10. *Risk and issue discussion with PM-JLTV engineers, etc.*

Assessment Metrics

Lesson: Before performing the assessment, a detailed metric has to be developed and agreed upon for the technologies between the program and IRT. The metric should contain specific detail technical requirements for each CTE, verification methods and acceptance criteria.

Data Collection and Organization

There were a lot of engineering supporting documents for the entire program. Only the ones that were relevant to the CTEs and technology concerns needed to be reviewed. Having the specific technology information organized allowed the SMEs to complete their assessments quickly.

Lesson: Rather than having the SMEs to locate the engineering information they need to make the assessment, locate and catalogue all relevant technical data (M&S results, test data and reports, failure incidences and corrective actions, engineering analysis, etc.) so they can easily refer to them while performing the assessment.

Technical Risk Assessment Process

1. Detail SME Assessment Method (Test Based)
2. TRL Calculator Method (Tasks Based)

Detail SME Assessment Method

1. Technical requirement identification

   Identify all related CDD and PD engineering requirements, acceptance criteria for the CTEs and IRT concerns based on TRL6 definition.

2. Data collection

   Collect information such as technical requirements, acceptance criteria, test data including failure incidence reports, failure analysis and corrective action reports, relevant CDR presentations, risk and requirement compliance matrices.

3. Substantiation package preparation

   Catalogue data by technology and contractor. Develop requirement and test data matrix for each technology so SMEs could find them quickly

4. Technical risk assessment and report

   Based on objective test data, engineering design and integration supporting documents, manufacturing information and SMEs' relevant experience, write up assessments with rationale.

Lessons Learned on the Detailed SME Methodology

Lesson: Failure to meet requirement does not necessarily mean TRL < 6. In case of non-compliance, the SMEs will review the corrective action taken and determine if there is an unacceptable risk for the EMD Phase. A justification will be required.

Lesson: To provide a more comprehensive technical risk assessment, in addition to Technology Readiness Level (TRL), it is recommended to include Manufacturing Readiness Level (MRL) and System Readiness Level (SRL) in the assessment especially if there are significant manufacturing and integration risks or issues during the Technology Development (TD) Phase.

Lesson: Many reliability & performance tests, failure root causes and corrective action reports were not complete when maturity assessments were made. It is better to update the assessments at the end of the test phase after test & evaluation engineers summarize the test results.

TRL Calculator Process

TRL Calculator Process

- TRL Calculator version 2.2 was used for the TRL analysis.
- This version of the Calculator was released by AFRL in May, 2004.
- The original version was released by the Air Force Research Lab around 2002.
- It provides a snap-shot of what a technology's maturity level was at a given time.
- There are three main categories of tasks in maturing a technology.
  1. Technical (TRL) – measures the technical maturity of the technology;
  2. Manufacturing (MRL) – measures the readiness of the production system to manufacture the technology being developed; and
  3. Programmatic (PRL) – measures program management concerns of each technology.
- For each technology, the generic list of tasks has to be tailored for the assessment.
- The percent completion for each task is required with justification.

Lesson: The aggregate TRL produced by the TRL Calculator depends on the worst of the TRL, MRL and PRL rating. A low TRL may be caused by programmatic elements rather than the technology itself. Detail interpretation of each calculated rating is required.

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BACKUP SLIDES

Technology Risk and Technical Risk

- Technology Risk = the risk that a technology, necessary for a capability, will not mature within the required time frame'. TRL can be used as a filter for assessing technology readiness (i.e., maturity and feasibility) of new technologies and give an indication of the technical challenge ahead.
- Technical Risk (System): the risk that a system will not reach its performance goals, development will not be within the specified time frame and/or it will cost more than estimated owing to difficulties experience with technical aspects; the risk associated with systems, their integration with other systems and their implementation.
- Technical Assessment: Technology assessment is a subset of technical assessment.
- Risk Management: Technology development can be considered a subset of risk management and as such should be a primary component of the risk assessment.

Source: Technology Readiness & Technical Risk Assessment for the Australian Defense Origanisation , Terry Moon, Jim Smith, Stephen Cook, 2004.

Appendix B
TRL Definitions

Technology Readiness Level Definitions, Descriptions, and Supporting Information			
TRL	Definition	Description	Supporting Information
1	Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development (R&D). Examples might include paper studies of a technology's basic properties.	Published research that identifies the principles that underlie this technology. References to who, where, when.
2	Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.	Publications or other references that outline the application being considered and that provide analysis to support the concept.
3	Analytical and experimental critical function and/or characteristic proof of concept.	Active R&D is initiated. This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.	Results of laboratory tests performed to measure parameters of interest and comparison to analytical predictions for critical subsystems. References to who where, and when these tests and comparisons were performed. Examples include "high fidelity" laboratory integration of components.
4	Component and/or breadboard validation in a laboratory environment.	Basic technological components are integrated to establish that they will work together This is relatively "low fidelity" compared with the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.	System concepts that have been considered and results from testing laboratory-scale breadboards(s). References to who did this work and when. Provide and estimate of how breadboard hardware and test results differ from the expected system goals.

Appendix B
TRL Definitions

SYSTEMS ENGINEERING AND INTEGRATION

Technology Readiness Level Definitions, Descriptions, and Supporting Information			
TRL	**Definition**	**Description**	**Supporting Information**
5	Component and/or breadboard validation in a relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.	Results from testing a laboratory breadboard system are integrated with other supporting elements in a simulated operational environment. How does the "relevant environment" differ from the expected operational environment? How do the test results compare with expectations? What problems, if any, were encountered? Was the breadboard system refined to more nearly match the expected system goals.
6	System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up I a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in a simulated operational environment.	Results from laboratory testing of a prototype system that is near the desired configuration in terms of performance, weight, and volume. How did the test environment differ from the operational environment? Who performed the tests? How did the test compare with expectations? What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before moving to the next level?
7	System prototype demonstration in an operational environment.	Prototype near or at planned operational system. Represents major step up from TRL 6 by requiring demonstration of an actual system prototype in an operational environment (e.g., in an aircraft, in a vehicle, or in space)	Results from testing a prototype system in an operational environment. Who performed the tests? How did the test compare with expectations? What problems, if any, were encountered? What are/were the plans options, or actions to resolve problems before moving to the next level?

Appendix B TRL Definitions

Technology Readiness Level Definitions, Descriptions, and Supporting Information			
TRL	**Definition**	**Description**	**Supporting Information**
8	Actual system completed and qualified through test and demonstration.	Technology has been proven to work in its final form an under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation (DT&E) of the system in its intended weapon system to determine if it meets design specifications.	Results of testing the system in its final configuration under the expected range of environmental conditions in which it will be expected to operate. Assessment of whether it will meet its operational requirements. What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before finalizing the design?
9	Actual system proven through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation (OT&E). Examples include using the system under operational mission conditions.	OT&E reports.

Appendix B MRL Definitions

Manufacturing Readiness Level Definitions, Descriptions, and Phase			
MRL	**Definition**	**Description**	**Phase**
1	Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development (R&D). Examples might include paper studies of a technology's basic properties.	Pre Materiel Solution Analysis
2	Manufacturing concepts identified	This level is characterized by describing the application of new manufacturing concepts. Applied research translates basic research into solutions for broadly defined military needs. Typically this level of readiness includes identification, paper studies and analysis of material and process approaches. An understanding of manufacturing feasibility and risk is emerging.	Pre Materiel Solution Analysis
3	Manufacturing proof of concept developed	This level begins the validation of the manufacturing concepts through analytical or laboratory experiments. This level of readiness is typical of technologies in Applied Research and Advanced Development. Materials and/or processes have been characterized for manufacturability and availability but further evaluation and demonstration is required. Experimental hardware models have been developed in a laboratory environment that may possess limited functionality.	Pre Materiel Solution Analysis
4	Capability to produce the technology in a laboratory environment.	This level of readiness acts as an exit criterion for the Materiel Solution Analysis (MSA) Phase approaching a Milestone A decision. Technologies should have matured to at least TRL 4. This level indicates that the technologies are ready for the Technology Development Phase of acquisition. At this point, required investments, such as manufacturing technology development, have been identified. Processes to ensure manufacturability, producibility, and quality are in place and are sufficient to produce technology demonstrators. Manufacturing risks have been identified for building prototypes and mitigation plans are in place. Target cost objectives have been established and manufacturing cost drivers have been identified. Producibility assessments of design concepts have been completed. Key design performance parameters have been identified as well as any special tooling, facilities, material handling and skills required.	Materiel Solution Analysis leading to a MS-A decision.

Appendix B
MRL Definitions

SYSTEMS ENGINEERING AND INTEGRATION

Manufacturing Readiness Level Definitions, Descriptions, and Phase			
MRL	**Definition**	**Description**	**Phase**
5	Capability to produce prototype components in a production relevant environment	This level of maturity is typical of the mid-point in the Technology Development Phase of acquisition, or in the case of key technologies, near the mid-point of an Advanced Technology Demonstration (ATD) project. Technologies should have matured to at least TRL 5. The industrial base has been assessed to identify potential manufacturing sources. A manufacturing strategy has been refined and integrated with the risk management plan. Identification of enabling/critical technologies and components is complete. Prototype materials, tooling and test equipment, as well as personnel skills have been demonstrated on components in a production relevant environment, but many manufacturing processes and procedures are still in development. Manufacturing technology development efforts have been initiated or are ongoing. Producibility assessments of key technologies and components are ongoing. A cost model has been constructed to assess projected manufacturing cost.	Technology Development Phase
6	Capability to produce a prototype system or subsystem in a production relevant environment	This MRL is associated with readiness for a Milestone B decision to initiate an acquisition program by entering into the Engineering and Manufacturing Development (EMD) Phase. It is normally seen as the level of manufacturing readiness that denotes acceptance of a preliminary system design. An initial manufacturing approach has been developed. The majority of manufacturing processes have been defined and characterized, but there are still significant engineering and/or design changes in the system itself. However, preliminary design has been completed and producibility assessments and trade studies of key technologies and components are complete. Prototype manufacturing processes and technologies, materials, tooling and test equipment, as well as personnel skills have been demonstrated on systems and/or subsystems in a production relevant environment. Cost, yield and rate analyses have been performed to assess how prototype data compare to target objectives, and the program has in place appropriate risk reduction to achieve cost requirements or establish a new baseline. This analysis should include design trades. Producibility considerations have shaped system development plans. The Industrial Capabilities Assessment (ICA) for Milestone B has been completed. Long-lead and key supply chain elements have been identified.	Technology Development Phase leading to a MS-B decision

Appendix B
MRL Definitions

SYSTEMS ENGINEERING AND INTEGRATION

Manufacturing Readiness Level Definitions, Descriptions, and Phase			
MRL	**Definition**	**Description**	**Phase**
7	Capability to produce systems, subsystems, or components in a production representativ e environment	This level of manufacturing readiness is typical for the mid-point of the Engineering and Manufacturing Development (EMD) Phase leading to the Post- CDR Assessment. Technologies should be on a path to achieve TRL 7. System detailed design activity is nearing completion. Material specifications have been approved and materials are available to meet the planned pilot line build schedule. Manufacturing processes and procedures have been demonstrated in a production representative environment. Detailed producibility trade studies are completed and producibility enhancements and risk assessments are underway. The cost model has been updated with detailed designs, rolled up to system level, and tracked against allocated targets. Unit cost reduction efforts have been prioritized and are underway. Yield and rate analyses have been updated with production representative data. The supply chain and supplier quality assurance have been assessed and long-lead procurement plans are in place. Manufacturing plans and quality targets have been developed. Production tooling and test equipment design and development have been initiated.	Engineering and Manufacturing Development Phase leading to a Pro Critical Design Review assessment
8	Pilot line capability demonstrated ; Ready to begin Low Rate Initial Production	This level is associated with readiness for a Milestone C decision, and entry into Low Rate Initial Production (LRIP). Technologies should have matured to at least TRL 7. Detailed system design is complete and sufficiently stable to enter low rate production. All materials, manpower, tooling, test equipment and facilities are proven on pilot line and are available to meet the planned low rate production schedule. Manufacturing and quality processes and procedures have been proven in a pilot line environment and are under control and ready for low rate production. Known producibility risks pose no significant challenges for low rate production. Cost model and yield and rate analyses have been updated with pilot line results. Supplier qualification testing and first article inspection have been completed. The Industrial Capabilities Assessment for Milestone C has been completed and shows that the supply chain is established to support LRIP.	Engineering and Manufacturing Development Phase leading to a Milestone C decision

Appendix B
MRL Definitions

SYSTEMS ENGINEERING AND INTEGRATION

Manufacturing Readiness Level Definitions, Descriptions, and Phase			
MRL	**Definition**	**Description**	**Phase**
9	Low rate production demonstrated; Capability in place to begin Full Rate Production	At this level, the system, component or item has been previously produced, is in production, or has successfully achieved low rate initial production. Technologies should have matured to TRL 9. This level of readiness is normally associated with readiness for entry into Full Rate Production (FRP). All systems engineering/design requirements should have been met such that there are minimal system changes. Major system design features are stable and have been proven in test and evaluation. Materials, parts, manpower, tooling, test equipment and facilities are available to meet planned rate production schedules. Manufacturing process capability in a low rate production environment is at an appropriate quality level to meet design key characteristic tolerances. Production risk monitoring is ongoing. LRIP cost targets have been met, and learning curves have been analyzed with actual data. The cost model has been developed for FRP environment and reflects the impact of continuous improvement.	Production and Deployment Phase leading a Full Rate Production (FRP) decision
10	Full Rate Production demonstrated and lean production practices in place	This is the highest level of production readiness. Technologies should have matured to TRL 9. This level of manufacturing is normally associated with the Production or Sustainment phases of the acquisition life cycle. Engineering/design changes are few and generally limited to quality and cost improvements. System, components or items are in full rate production and meet all engineering, performance, quality and reliability requirements. Manufacturing process capability is at the appropriate quality level. All materials, tooling, inspection and test equipment, facilities and manpower are in place and have met full rate production requirements. Rate production unit costs meet goals, and funding is sufficient for production at required rates. Lean practices are well established and continuous process improvements are ongoing.	Full Rate Production / Sustainment

Appendix B
SRL Definitions

SYSTEMS ENGINEERING AND INTEGRATION

System Readiness Level Definitions, Descriptions, and Level of Integration			
SRL	**Definition**	**Description**	**Level of Integration**
7	System prototype demonstration in an operational environment	Prototype near, or at, planned operational system. Represents a major step up from SRL 6, requiring demonstration of an actual system prototype in an operational environment such as an aircraft, vehicle, or space, including interaction with external systems.	Fully integrated with prototype System interfaces qualified in an operational environment.
8	Actual system completed and qualified through test and demonstration	System has been proven to work in its final form and under expected conditions, including integration with external systems. In almost all cases, this SRL represents the end of true system development. Examples include test and evaluation of the system in its intended context and operational architecture to determine if it meets design specifications.	Final production design validated demonstrating internal and external integration.
9	Actual system proven through successful mission operations	Actual application of the system in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include operational test and evaluation. Examples include	

Appendix B
SRL Definitions

SYSTEMS ENGINEERING AND INTEGRATION

System Readiness Level Definitions, Descriptions, and Level of Integration			
SRL	**Definition**	**Description**	**Level of Integration**
1	Basic principles observed and reported.	Lowest level of system readiness. Scientific research begins to be translated into applied research and development (R&D). Examples might include paper studies of a system's basic properties.	Interface requirements understood at concept level only. Impact on other systems is understood at a concept level only.
2	System concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.	
3	Analytical and experimental critical function and/or characteristic proof of concept.	Active R&D is initiated. This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the system. Examples might include COTS components that are not yet integrated or representative.	Analytical assessment conducted to establish interface requirements.
4	Component and/or breadboard validation in a laboratory environment.	Basic system components are integrated to establish that they will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.	Interface requirements specified and understood. The likely impact on interfaced systems is generally understood.
5	Component and/or breadboard validation in relevant environment	Fidelity of system components increases significantly. The basic system components are integrated with reasonably realistic supporting elements so the total system can be tested in a simulated environment. Examples include "high-fidelity" laboratory integration of components into system elements.	Interfaces partially demonstrated at System/Subsystem level in a synthetic environment. Impact on other system is understood, specified and quantified.
6	System/subsystem model or prototype demonstration in a relevant environment	Representative model or prototype system, which is demonstrated in a well-simulated operational environment, including interaction with simulations of key external systems.	Interfaces demonstrated at system level in a synthetic / high fidelity environment.

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